Section 2: Calibration, estimation and results of a general equilibrium model[1]

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[1] DISCLAIMER: The views expressed here are my own and do not necessarily represent those of the St. Edmund Hall, U. of Oxford or the Saïd Business School, nor the Central Bank of Chile or its Board. Based on "A Financial Stability Analysis for the Chilean Economy" (Kazakova, Martinez, Peiris, Tsomocos, 2019); "Macroprudential Policy Analysis in an Estimated DSGE Model with a Heterogeneous Banking System: an Application to Chile"(Martinez, Peiris, Tsomocos, 2020)

Models, frictions and data

Modern analysis must be consistent with general equilibrium reasoning. GE reasoning must be consistent with time series data.

The data we use is driven by the model blocks

- Use as a core a SOE NK-model:
  - GDP, consumption, inflation, interest rate, government debt, government spending, exchange rate, current account
- Introduce endogenous financial frictions through wedges:
  - loans, debt-equity ratio
- Introduce optimizing financial sector:
  - bank equity, bank capital adequacy ratios, bank bond holdings, bank deposits, bank loans, bank non-performing loans rates

We need to obtain simulations at least at 2nd order level to utilize the power of the model and estimation.

Dynamic Models

- **Financial frictions and business cycles** (Bernanke et. al., 1999, Gertler and Kiyotaki, 2010, Jermann and Quadrini, 2012, Mendoza, 2012, Christiano, Motto, Rostagno, 2014, Iacoviello, 2015, Gerali et. al., 2010)
- **Macro effects of capital requirements** (Van den Heuvel, 2008, Clerc et. al., 2015, Begenau, 2018)
- **Shadow banking in business cycle models** (Begenau and Landvoigt, 2017, Gertler et. al., 2016, Meeks et. al., 2017, Nelson et. al., 2017, Feve and Pierrard, 2017, Moreira and Savov, 2017)

The Challenge

Useful normative analysis requires the interaction between households, banks, the production sector, the government and the external sector

Goodhart et al (2006), Tsomocos (2003) etc presents a unified framework to study this within a General Equilibrium model. Estimated dynamic models used by policymakers include

- the FRBNY DSGE model (but banks are risk neutral and only one type of debt)
- the ECB
- the IMF

Macroprudential policy analysis difficult - capital and portfolio decisions matter.

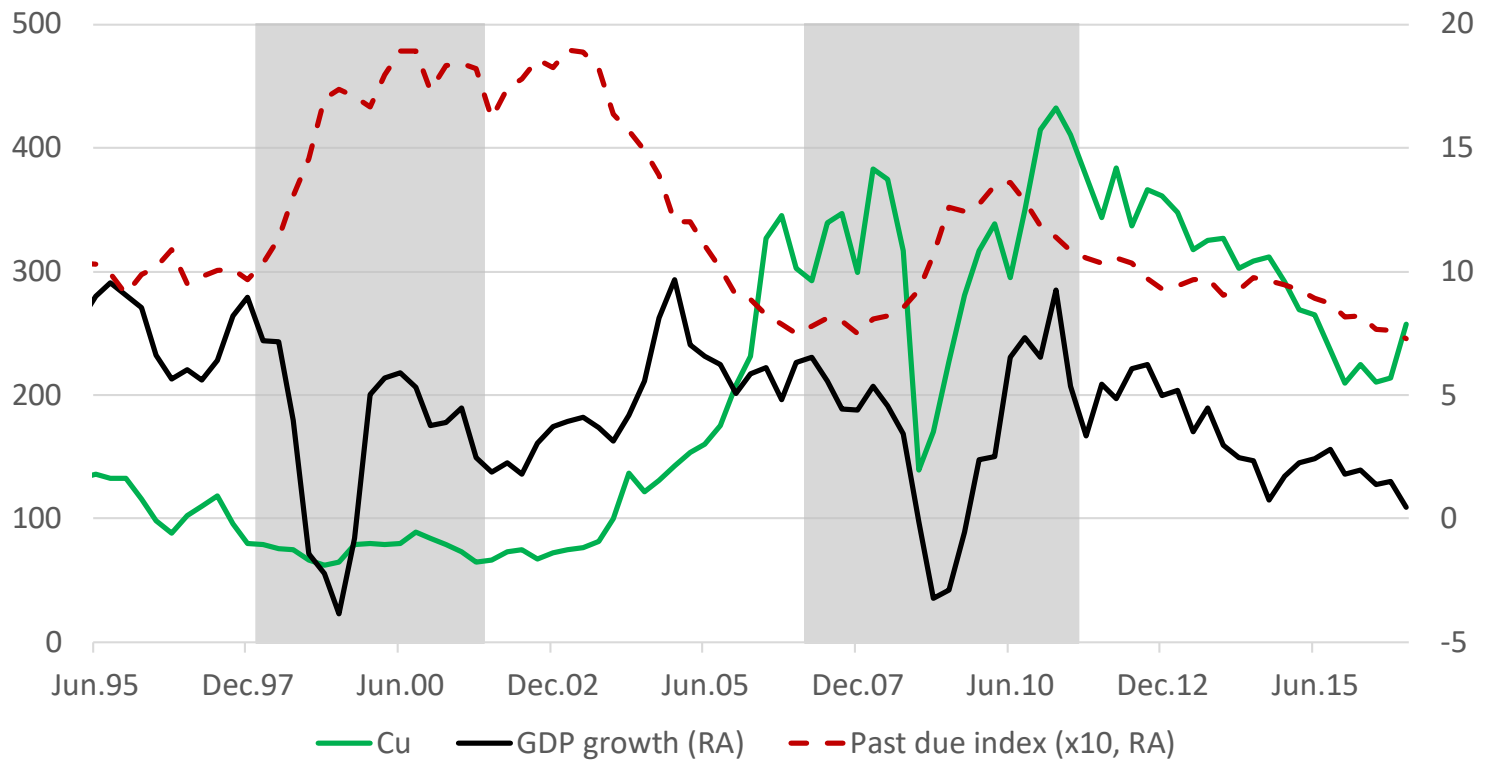
"Macroprudential Policy Analysis in an Estimated DSGE Model with a Heterogeneous Banking System: an Application to Chile"

- Chile has experienced three relevant episodes in the last 40 years with different degrees of relevance and policy/regulatory environments.
- The current situation is the result of convergence to an open economy with safer banking system. Chile has inflation targeting with free floating exchange rate, which acts as a natural stabilizer of international shocks.
- However, there is still dependence of copper prices that may feedback to the financial sector directly or **indirectly**.

Commodity price shocks' role

- In particular, recent periods of fragility seem related to commodity price fluctuations...

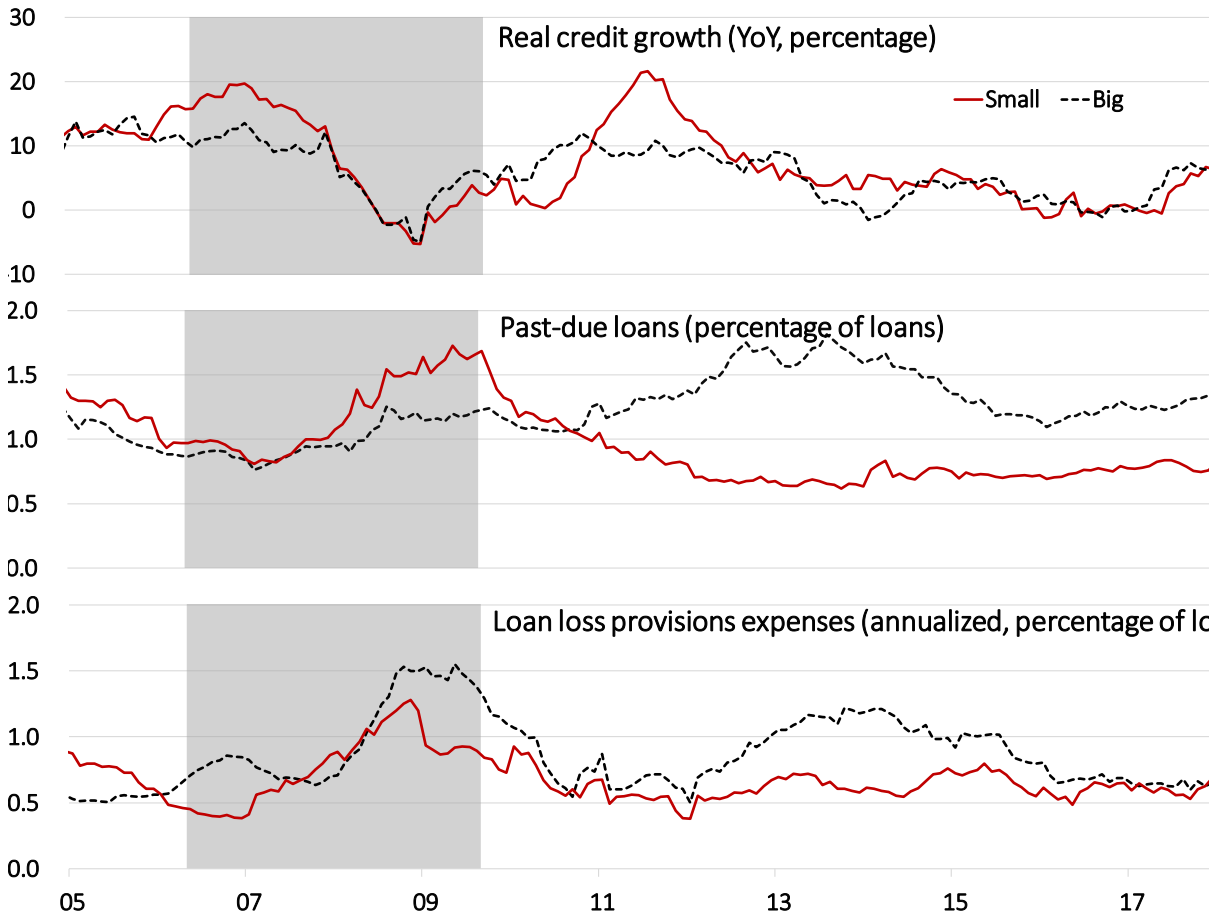
Figure: Financial Fragility and Economic Activity (percentage)



Source: Own elaboration. Grey areas based on Martinez et al. (2018).

The role of bank heterogeneity

Figure: Commercial sector credit activity and risks by bank's size in Chile



Source: Own elaboration. Grey areas based on Martinez et al. (2018).

Focus of Analysis

Our paper concerns **macroprudential regulation/monitoring** in **fragility times** with macroeconomic shocks being amplified due to the presence of **pecuniary externalities**. The two sources of the externalities are:

- Cost of default
- Collateral constraints dependent on market valuation of capital

Banking sector features:

- Big and small banks
- Perfect competition
- Ex post heterogeneity manifested in idiosyncratic shocks experienced by small banks

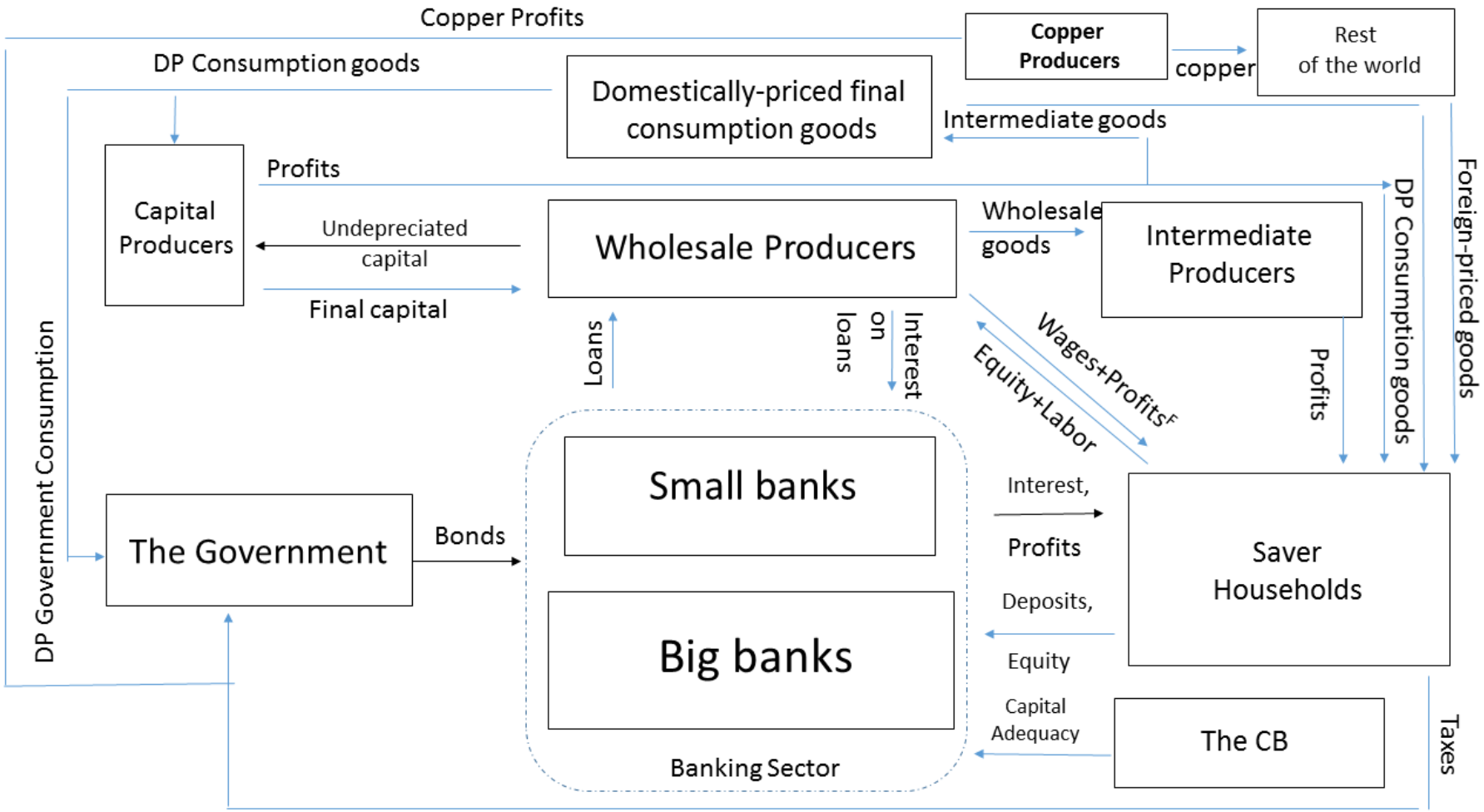
Model structure

- New-Keynesian DSGE model with nominal rigidities.
- Considers a commodity exporter Small Open Economy.
- Assume that all goods are tradable and there are no barriers to trade.
- There is households, firms, external sector, Central Bank, Regulator and Government.
- Heterogenous 2-period lived Firms with idiosyncratic risk and default.
- Heterogenous 2-period lived banks, and capital requirements.
- Hence, there is default - for secured and collateralized loans - and capital requirements.
- Consider further bank heterogeneity in the form of systemic and small banks.

Implication

Endogenous (strategic) default allows modeling risk taking behavior by firms, and justifies prudential regulation of banks and monetary policy.

Flow of funds



Formulation: firms (ex ante)

OLG structure

- Two period lived firms
- Secured vs unsecured borrowing
- **t=0**: Firms issue non-state-contingent nominal unsecured debt(credit)to banks.
- **t=1**: Firms liquidate assets, and pay dividends net of renegotiation costs depending on their default decisions and the business cycle fluctuations.

$$p_t^K k_{t+1}^w + T^w + \Gamma^w(\mu_{t+1}^{w,s}, \mu_{t+1}^{w,u}, k_{t+1}^w) = \mu_{t+1}^w + e_t^{w,total}, \tag{1}$$

where $\mu_{t+1}^w = \mu_{t+1}^{w,s} + \mu_{t+1}^{w,u}$ and $e_t^{w,total} = e_t^w + (1-\tau)p_t^K k_t^w$

$$\mathbb{E}(1 + r_{t+1}^{w,s})\mu_{t+1}^{w,s} \leq coll(1-\tau)k_{t+1}^w \, \mathbb{E}\, p_{t+1}^K \tag{2}$$

Formulation: firms (ex post)

- 'Lucky' vs 'unlucky' firms: probability of default θ^w is the prob. of $\underline{A_t}$
- δ_t^w - loss given default
- Cost of negotiating the debt $\frac{\Omega_{t+1}^w}{1+\psi}\left(\delta_{t+1}^w \mu_{t+1}^{w,u}(1+r_{t+1}^{w,u})\right)^{1+\psi}$

$$\begin{aligned}\Pi_{t+1}^w = p_{t+1}^w A_{t+1}^w (k_{t+1}^w)^\alpha (l_{t+1}^w)^{1-\alpha} \; - (1-\delta_{t+1}^w)\mu_{t+1}^{w,u}(1+r_{t+1}^{w,u}) - \mu_{t+1}^{w,s}(1+r_{t+1}^{w,s}) \\ - w_{t+1} l_{t+1}^w - \frac{\Omega_{t+1}^w}{1+\psi}\left(\delta_{t+1}^w \mu_{t+1}^{w,u}(1+r_{t+1}^{w,u})\right)^{1+\psi} + p_{t+1}^K k_{t+1}^w (1-\tau) + T^{w,prof}\end{aligned} \tag{3}$$

- Firms' decision to default creates pecuniary externality
- Higher expected default rate raises the interest rate ax ante
- Macro variable:

$$\Omega_t^w = \Omega_{ss}^w \left(\frac{\mu_{ss}^{w,u}(1+r_{ss}^{w,u})}{GDP_{ss}}\right)^\omega (\delta_{ss}^w)^\gamma \left(\frac{GDP_t}{\mu_t^{w,u}(1+r_t^{w,u})}\right)^\omega \frac{1}{(\delta_t^w)^\gamma}. \tag{4}$$

Systemically important banks

- New-born systemically important large banks are capitalised with equity of e_t^{big}.
- They accept deposits from households, extend secured and unsecured loans to firms.

The first period budget constraint of a systemically important bank is given by

$$\mu_{t+1}^{big,s} + \mu_{t+1}^{big,u} + \Gamma^{big}(\mu_{t+1}^{big,s}, \mu_{t+1}^{big,u}, d_{t+1}^{big}) = d_{t+1}^{big} + e_t^{big} + T^{big} \tag{5}$$

The capital adequacy ratio is defined as the ratio of bank capital to risk weighted assets net of reserves (rwa_t^{big}) :

$$k_t^{big} = \frac{e_t^{big}}{rwa_t^{big}} = \frac{e_t^{big}}{(\bar{rw}\mu_{t+1}^{big,u} + \bar{rw}\mu_{t+1}^{big,s})} \tag{6}$$

Big banks then choose how much of secured and unsecured debt to lend out to firms:

$$\Pi_{t+1}^{big} = \theta^w(1 + r_{t+1}^{w,u})(1 - \delta_{t+1}^w)\mu_{t+1}^{big,u} + (1 - \theta^w)(1 + r_{t+1}^{w,u})\mu_{t+1}^{big,u} + \\ + (1 + r_{t+1}^{w,s})\mu_{t+1}^{big,s} - (1 + r_{t+1}^d)d_{t+1}^{big} + T^{big,prof}, \tag{7}$$

Given $\left\{\delta_{t+1}^w, r_{t+1}^{w,u}, r_{t+1}^{w,s}, r_{t+1}^d\right\}$, banks maximize:

$$\max_{\mu_{t+\mathbf{1}}^{big,u}, \mu_{t+\mathbf{1}}^{bank,s}, d_{t+\mathbf{1}}^{big}} \mathbb{E}_t \beta_t^h \frac{(\Pi_{t+1}^{big})^{1-\varsigma_{big}}}{1 - \varsigma_{big}} - a_{cap} 0.5[k_t^{big} - \bar{k}^{big}]^2 \tag{8}$$

Small banks

Small banks have the following BC:

$$\mu_{t+1}^{small,s} + \mu_{t+1}^{small,u} + \Gamma^{small}(\mu_{t+1}^{small,s}, \mu_{t+1}^{small,u}, d_{t+1}^{small}) = d_{t+1}^{small} + e_t^{small} \tag{9}$$

Lucky small bank receives a profit:

$$\bar{\Pi}_{t+1}^{small} = (1 + r_{t+1}^{w,u})\mu_{t+1}^{small,u} + (1 + r_{t+1}^{w,s})\mu_{t+1}^{small,s} - (1 + r_{t+1}^{d})d_{t+1}^{small}, \tag{10}$$

Unlucky small bank receives a profit:

$$\underline{\Pi}_{t+1}^{small} = (1 + r_{t+1}^{w,u})(1 - \delta_{t+1}^{w})\mu_{t+1}^{small,u} + (1 + r_{t+1}^{w,s})\mu_{t+1}^{small,s} - (1 + r_{t+1}^{d})d_{t+1}^{small}, \tag{11}$$

For a small bank capital adequacy ratio looks like:

$$k_t^{small} = \frac{e_t^{small}}{rwa_t^{small}} = \frac{e_t^{small}}{(\bar{rw}\,\mu_{t+1}^{small,u} + \bar{rw}\,\mu_{t+1}^{small,s})} \tag{12}$$

Given $\left\{\delta_{t+1}^{w}, r_{t+1}^{w,u}, r_{t+1}^{w,s}, r_{t+1}^{d}\right\}$**, banks maximize:**

$$\max_{\mu_{t+1}^{small,u}, \mu_{t+1}^{small,s}, d_{t+1}^{small}} \mathbb{E}_t \beta^{small}[(1 - \theta^{w})\frac{(\bar{\Pi}_{t+1}^{small})^{1-\varsigma_{small}}}{1 - \varsigma_{small}} + \theta^{w}\frac{(\underline{\Pi}_{t+1}^{small})^{1-\varsigma_{small}}}{1 - \varsigma_{small}}] - \tag{13}$$

$$- a_{cap}\,0.5[k_t^{small} - \bar{k}^{small}]^2 + \lambda^{small,uns}\frac{\mu_{t+1}^{small,u}}{\mu_{ss}^{small,u}}$$

The CB and the Government

- The Central Bank controls the interest rate i_t^b according to the following rule:

$$\frac{1+i_t^b}{1+i_{ss}^b} = \left(\frac{1+i_{t-1}^b}{1+i_{ss}^b}\right)^{\rho_i} \left(\frac{1+\pi_t^{cpi}}{1+\pi_{ss}^{cpi}}\right)^{1+\rho_\pi} \left(\frac{GDP_t}{GDP_{ss}}\right)^{\rho_{gdp}} \varepsilon_t^i, \tag{14}$$

- The Government owns the copper endowment and receives all the copper profits
- The Government Budget Constraint:

$$G_t + p_t^{imp} G_t^{imp} + B_{t-1}^g \frac{(1+i_{t-1}^b)}{1+\pi_t} + T^h + T^{w,prof} + T^{big} + T^{big,prof} = B_t^g + p_t^{c,dom} C_t + T^w \tag{15}$$

- The Government spending rule:

$$G_t = G_{ss} \left(\frac{GDP_{ss}}{GDP_t}\right)^{-\rho^{g,spend}} \tag{16}$$

- The Government supply of bonds rule:

$$B_t^g = B_{ss}^g \left(\frac{GDP_{ss}}{GDP_t}\right)^{b^{g,b}} \tag{17}$$

Selected Estimation results: Adjustment costs

			Post mean
firms'	secured loans	$a^{w,s}$	0.0866
	unsecured loans	$a^{w,u}$	0.0535
big banks'	secured loans	$a^{b,s}$	0.0055
	unsecured loans	$a^{b,u}$	0.0114
	deposits	$a^{b,d}$	0.0924
small banks'	secured loans	$a^{s,s}$	0.0013
	unsecured loans	$a^{s,u}$	0.0014
	deposits	$a^{s,d}$	0.1710

Regulation: Counter-Cyclical Capital Buffer (CCyB) and Liquidity Coverage Ratio (LCR)

- **Credit-to-GDP ratio CCyB**:

$$k_t^{bank} = k^{bank} + \rho^{capad,bank} log(gap_t^{gdp}) k_{ss}^{bank} (gap_t^{gdp})^{\eta^{ccyb}} \tag{18}$$

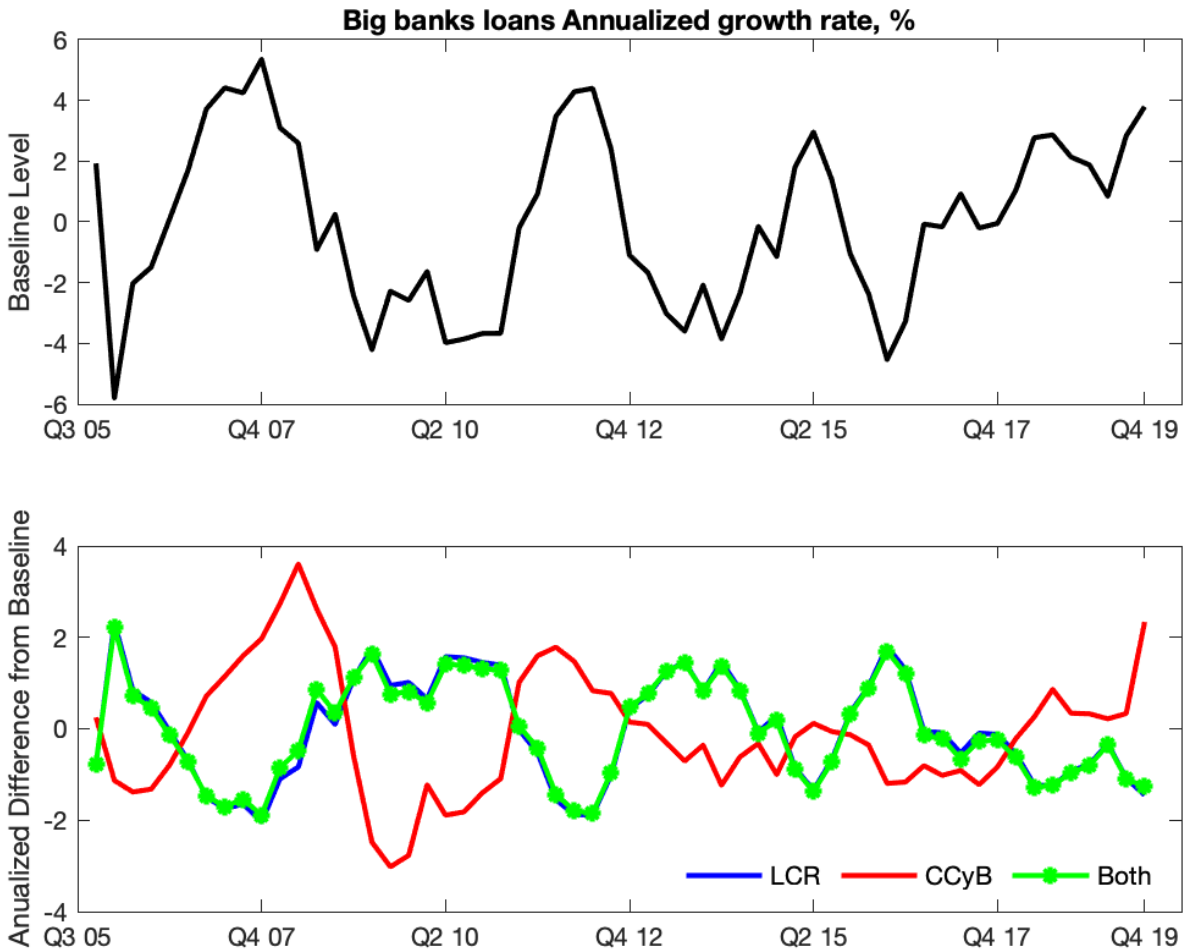
- **Credit-to-GDP ratio LCR**:

$$res_t^{bank} = \rho^{dep,res,bank} \left(\frac{d_{t+1}^{bank}}{d_{ss}^{bank}} - 1 \right) \tag{19}$$

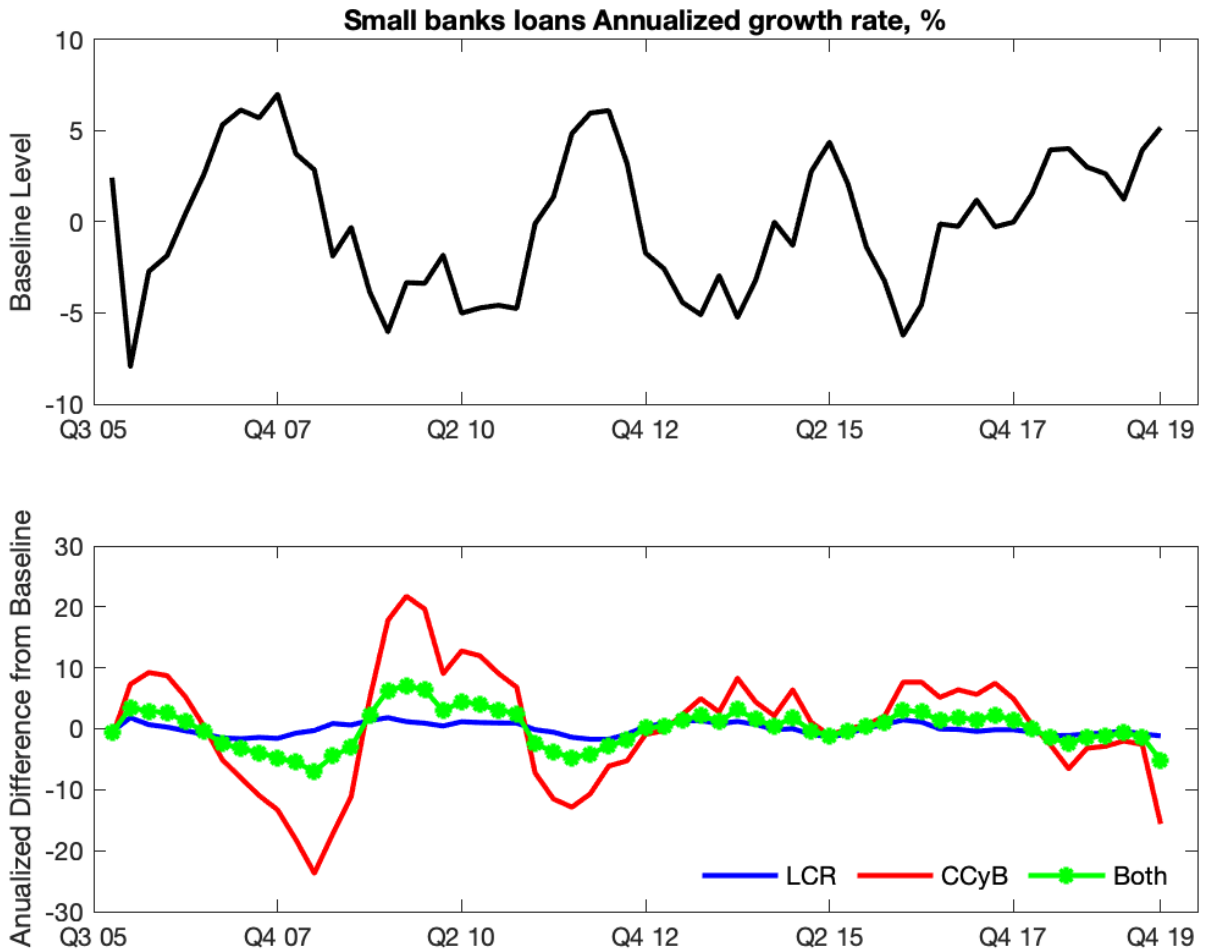
where η is chosen to maximimise household welfare and gap_t^{gdp} is defined as:

$$gap_t^{gdp} = \frac{\frac{\mu_{t+1}^{w}}{GDP_t}}{\frac{\mu_{ss}^{w}}{GDP_{ss}}}. \tag{20}$$

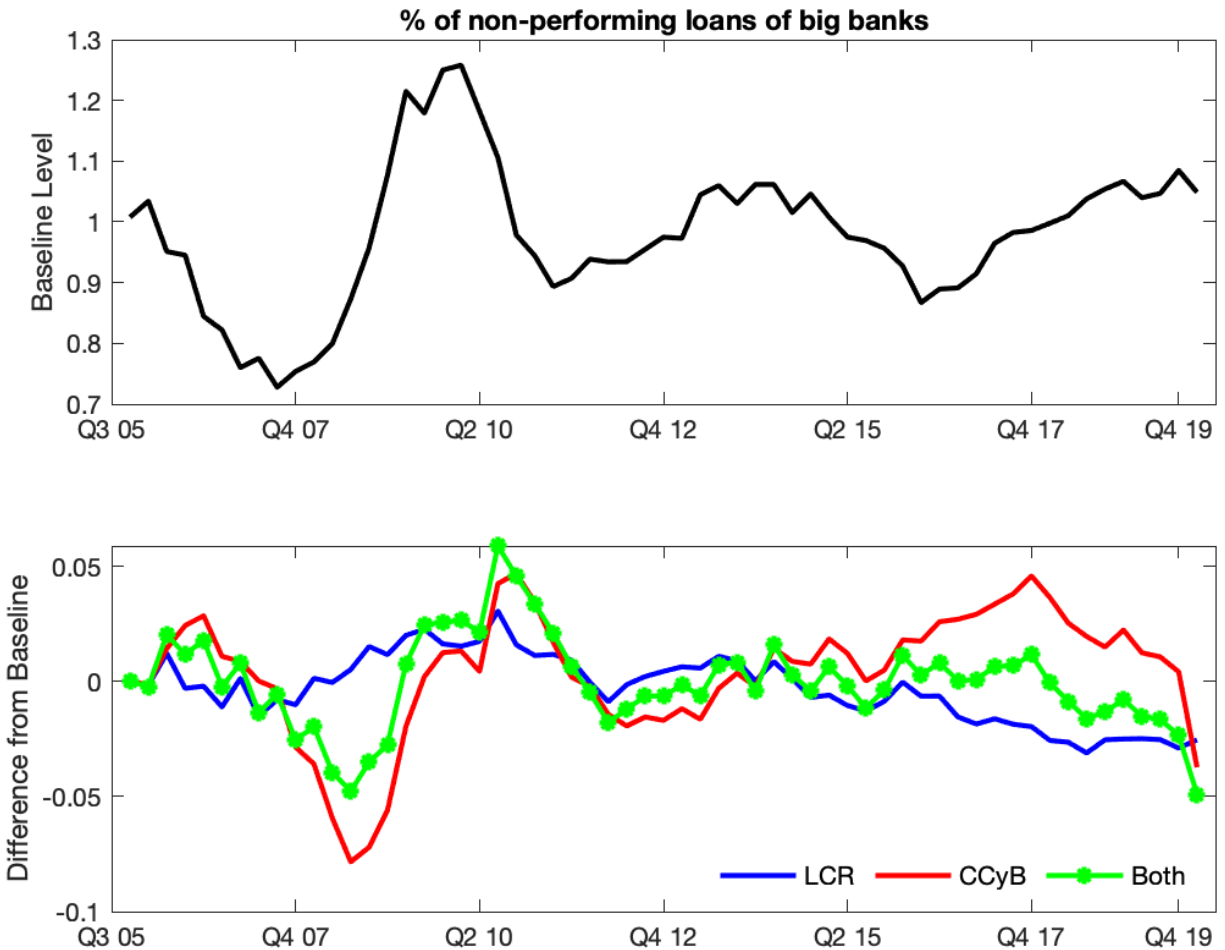
Counterfactual Historical path - Big Banks Loans



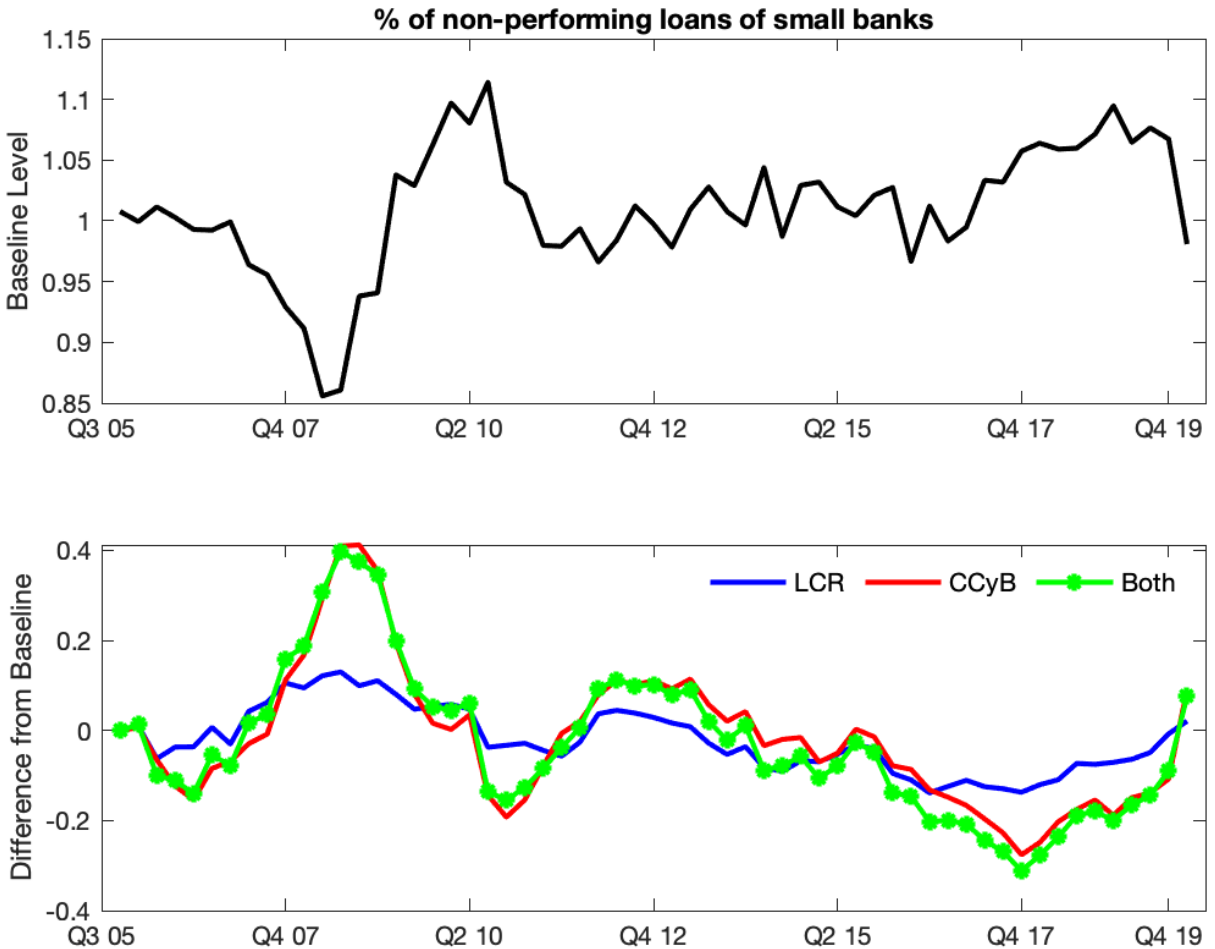
Counterfactual Historical path -Small Banks Loans



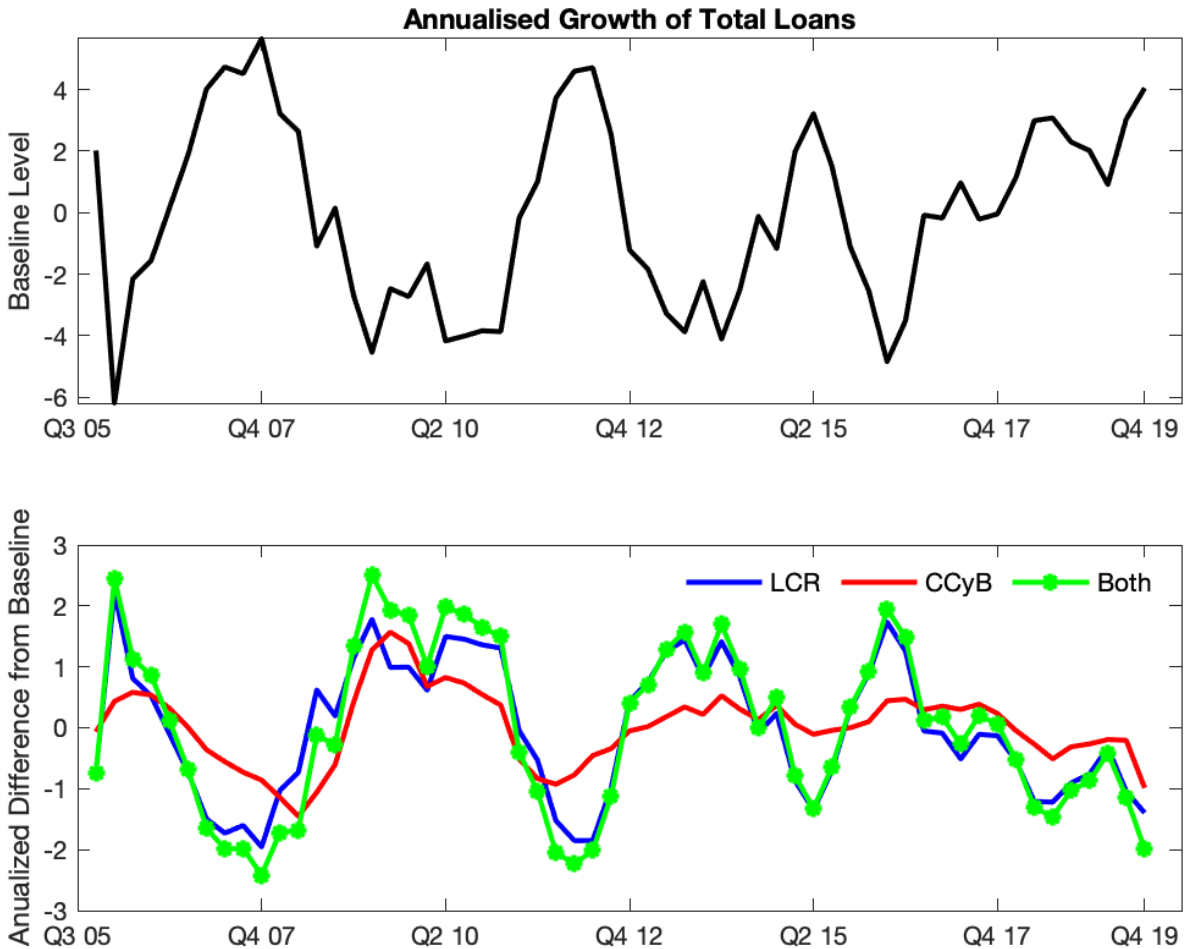
Counterfactual Historical path - Big Banks NPLs



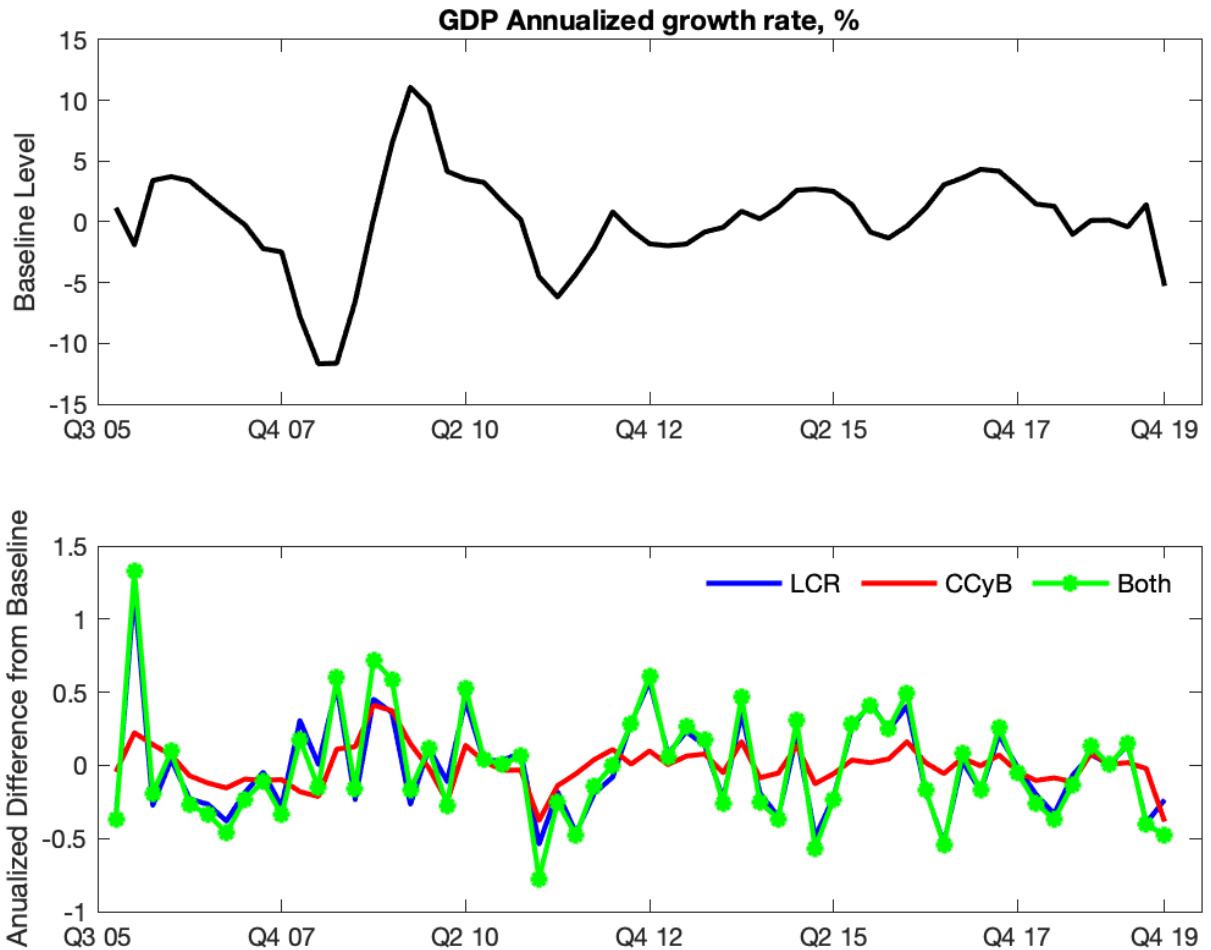
Counterfactual Historical path - Small Banks NPLs



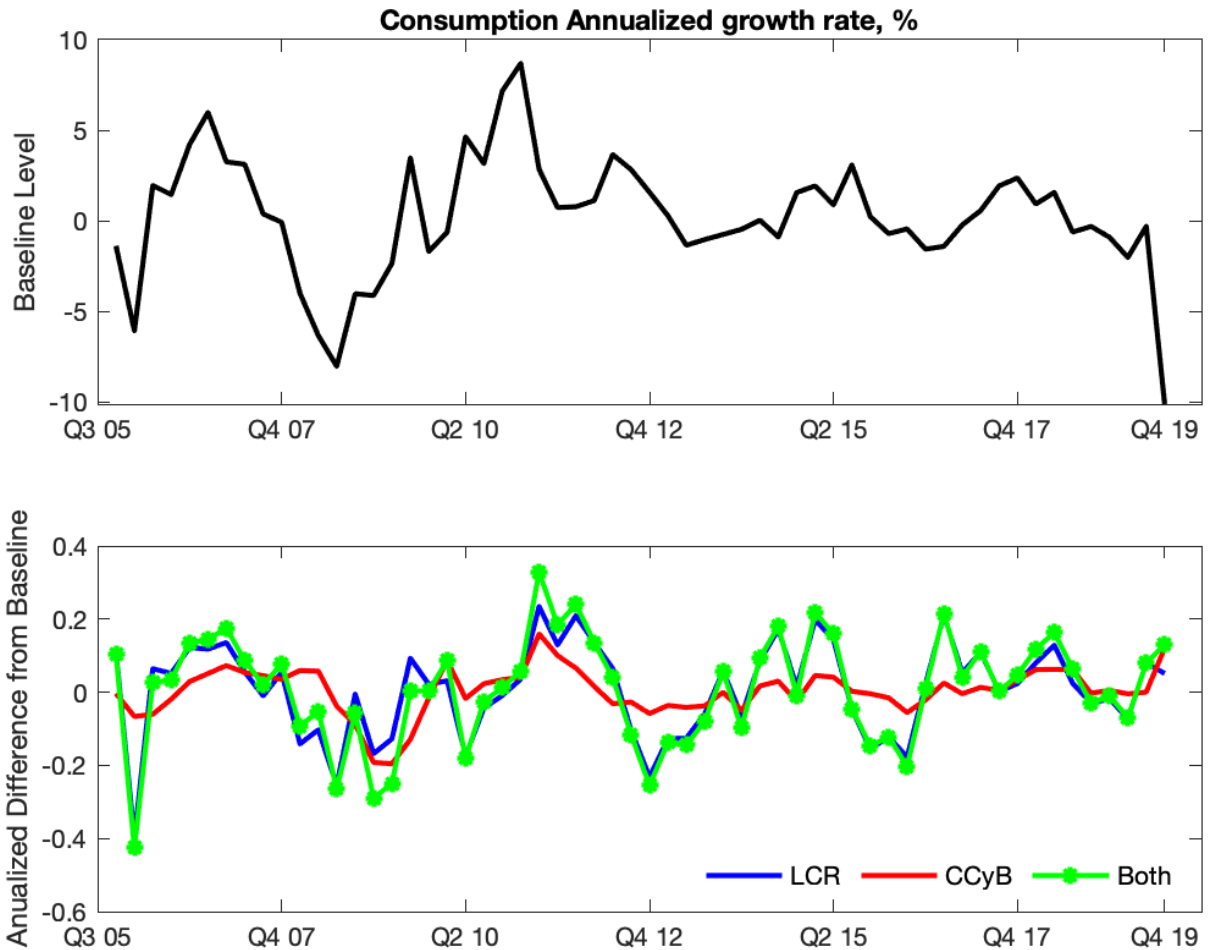
Counterfactual Historical path - Total Loans



Counterfactual Historical path - GDP



Counterfactual Historical path - Consumption



Conclusions

- Modern analysis must be consistent with general equilibrium reasoning. GE reasoning must be consistent with time series data.
- Financial and monetary policy should be seen as complementary.
- Modelling financial sector within an otherwise standard DSGE is necessary to account for the effect of both types of policies, given the relevance of the credit channel. Also, heterogeneity in the banking sector could act as an amplifier mechanism.
- Regarding to financial policy, the study of capital requirement effects should be done in the context of liquidity regulation.
- We find that for the case of a SOE, liquidity and CCyB regulations are reinforcing and allow to smooth the cycle, and improving welfare (i.e. GDP and specially Consumption).
- This is an ongoing agenda. We plan to include more features of the financial sectors and to study the effects in the middle run of Covid-19 shock and policy responses (e.g. special credit facilities, forbearance programs, among others).